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EFFECTS OF AN ELECTRONIC, MOTION-ACTIVATED SCARECROW ON
FORAGING BEHAVIOR IN NOCTURNAL, VERTEBRATE CROP PESTS IN
SOUTH AFRICA

A Capstone Experience/Thesis Project
Presented in Partial Fulfillment of the Requirements for
the Degree Bachelors of Science with
Honors College Graduate Distinction at Western Kentucky University

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2016

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ABSTRACT

The normal behaviors of animals can disrupt human activities, resulting in human wildlife conflict. In South Africa, nocturnal crop raiders are a significant source of human wildlife conflict for farmers. Major nocturnal pest animals are Cape porcupine (*Hystrix africaeaustralis*) and bushpig (*Potamochoerus larvatus*). Although methods of deterring animals from agricultural areas have been explored, nocturnal crop raiding remains difficult to mitigate. Most research studies focus on deterring non-human primates and elephants, but methods that may be successful in deterring such larger mammals are not necessarily effective at discouraging smaller, nocturnal crop raiders. This study examined the efficacy of a motion activated, multimodal scarecrow apparatus at discouraging nocturnal crop raiding behaviors in two study sites in Limpopo Province, South Africa. The scarecrow consisted of an orange flashing light and an iPod with speaker that played a 20-second sound file (randomly selected 26 sound files). Motion activated cameras recorded animals for up to 120 seconds per capture, and behaviors were recorded using an ethogram. I predicted that the multimodal scarecrow would decrease the duration of destructive behaviors (feeding and foraging) performed by nocturnal animals. Further, I predicted the multimodal scarecrow would cause the animals to run in response. If animals did not leave following the activation, I predicted the animals would perform more looking events as an indication of vigilance. Although eleven species were identified, only sample sizes for bushpig, Cape porcupine, and genets (*Genetta*) were sufficient for analysis. All three species spent significantly less time feeding and foraging

following the scarecrow activation. Mean feeding and foraging time for bushpig prior to the scarecrow activation was 15.44 s out of 20 s, compared with a mean of 7.11 s out of 20 s following activation ($N = 27$, $P = 0.00066$). Cape porcupine participated in feeding in foraging behavior for a mean of 14.25 s before the scarecrow and 11.00 s after ($N = 12$, $P = 0.046$). Genet, which were not differentiated by species, spent an average of 15.14 s feeding and foraging before the scarecrow was activated, and a mean of 8.0 s after activation ($N = 7$, $P = 0.028$). Only the sample size for bushpig was sufficient for analysis of running, which occurred significantly more often upon the activation of the scarecrow ($N = 15$, $P = 0.0003$, one tailed). The frequency of looking events was not significantly influenced by the scarecrow mechanism (for all samples, $P > 0.05$).

Although the scarecrow was not shown to increase vigilance in terms of frequency of looking events, it was successful in reducing the duration of destructive feeding and foraging behaviors, as well as causing bushpig to run away from the study sites. The motion-activated scarecrow mechanism provides a promising way to combat nocturnal crop raiding in bushpig, Cape porcupine, and genet, though further research must be conducted to examine long-term efficacy of the scarecrow.

Keywords: *Human Wildlife Conflict, Crop Raiding, Animal Behavior, Agriculture, South Africa, Scarecrow*

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CHAPTER 1

INTRODUCTION

Human wildlife conflict is a global problem, occurring when animal behaviors disrupt human activities, or when human activities have negative effects on life histories of animals. Although human wildlife conflict can be considered from the view of humans disrupting animal activity, in the context of conservation, human wildlife conflict often refers to actions by animals which are damaging or disruptive to humans (Madden, 2004). Causes of human wildlife conflict in Africa, for example, are usually attributed to animals feeding on farmers' crops, animals attacking domestic livestock, and instances of animals attacking humans (Madden 2004).

Nocturnal animals, such as Cape porcupine (*Hystrix africaeaustralis*) and bushpig (*Potamochoerus larvatus*), are reported by African farmers as being significant pest animals and participants in crop-raiding (Naughton-Treves and Treves, 2005). In heavily agricultural areas that are protected from larger crop-raiders, rodents such as porcupines can be destructive and difficult to deter (Sillero-Zubiri and Switzer, 2001). Nocturnal animals may be more at risk for lethal control methods due to lower human tolerance for nocturnal crop raiders (Treves, 2008). Additionally, because many nocturnal crop raiders are common, they are not protected by conservation laws from lethal pest management (Osborn and Hill, 2005).

A number of methods to prevent crop-raiding have been explored, including various types of fences, guards, lights, and alarms (Hsiao et al., 2013). Farmers may actively participate in the non-lethal deterrence method of “drive them away” (Osborn and Hill, 2005). Although hiring guards to deter pests is perceived as a very effective method (Hsiao et al., 2013), the expense and negative social effects of hired labor may be prohibitive (Mackenzie and Ahabyona, 2011). Additionally, the efficacy of active human crop raider deterrence methods is difficult to quantify, especially as many of the data are qualitative and anecdotal (Osborn and Hill, 2005). While preliminary studies suggest that guarding is effective at deterring diurnal, non-human primates (Osborn and Hill, 2005), nocturnal crop raider deterrence is less well explored.

Animal-activated scarecrows have short-term effectiveness in deterring deer from foraging (Beringer et al., 2003). Short-term deterrents may be useful in areas that experience high levels of crop-raiding before and during harvest time (Koehler et al., 1990). Because human-wildlife contact with crop-raiding species is greatest during harvest-time, a seasonal scarecrow may have a high efficacy in reducing pest foraging of crops. Because animals can habituate to traditional scarecrows, and other visual deterrents, quickly and easily (Osborn and Hill, 2005), the use of multiple sensory pathways is likely more effective than singular, visual cues at deterring crop raiders.

Bomford and O’Brien (1990) demonstrated that acoustic devices can be effective at deterring birds, but are less effective in deterring elephants. In their study, Bomford and O’Brien suggest that communicative sounds may be more effective at deterring animals than non-communicative sounds. This suggests that different types of sounds played by acoustic deterrents may result in different behavioral responses by animals.

Treves (2008) proposed that deterrents negatively impact “non-target wildlife.” However, since the scarecrow and scarecrow mechanism are confined to areas that are largely visited by known crop raiders, the risk of unintended disruption is minimized.

An ideal method of reducing human wildlife conflict due to nocturnal crop raiding would therefore be a mechanism by which nocturnal feeding is reduced, that does not require human guarding, and that has quantifiable success. Therefore, a motion-activated scarecrow may be a viable tool in the use of reduction of human wildlife conflict.

Because animal-activated scarecrows have had documented success in deterring foraging behavior (Beringer et al, 2003), an animal-activated scarecrow producing signals for multiple sensory pathways should be successful in reducing destructive, crop-raiding behavior of nocturnal pest animals. The efficacy of such a multimodal scarecrow can be measured by documenting how the animals respond to the scarecrow. If the multimodal scarecrow is an effective deterrent, its activation will correspond with a decrease in the time spent by animals performing damaging feeding/foraging behaviors, so that an animal will spend less time in damaging activities following the multimodal scarecrow activation compared to the time prior to the activation.

The multimodal scarecrow is intended to startle the animal and disrupt its damaging behavior (Gilsdorf et al., 2002); therefore, behaviors associated with a fear response should be observed. In the Gilsdorf et al. (2002) study, effective frightening methods are those that encourage an animal to leave an area that contains a resource the animal is seeking. Following the multimodal scarecrow stimulus, the animals should be motivated to leave the site. Pyke (1981) illustrates that animals prefer travel at optimal speeds that minimize energy expenditure. Running is usually only observed in animals

that are actively seeking to capture prey, or in animals that feel threatened and choose to flee based on fight or flight response (Pyke, 1981). Because crop-raiding animals in the present study are not pursuing prey, running behavior would suggest a response to a stimulus. If the multimodal scarecrow is a successful frightening device, animals should run in response to its activation.

Even if an animal does not leave a site following the activation of a frightening mechanism such as a scarecrow, the animal should display some behaviors that indicate the device is affecting normal behavior (Gilsdorf et al., 2002). Animals should demonstrate vigilance, indicating that the device is being perceived by them as a possible threat (Gilsdorf et al., 2002). Vigilance may be conducted through scanning behaviors and other observations of surroundings (Burger and Gochfeld, 1994). Because the present study focuses on nocturnal animals, the number of times an animal looks is easily recorded by examining eye shine. Animals should perform more discrete look events following the activation of the multimodal scarecrow, indicating that the animal is assessing the multimodal scarecrow as a possible danger.

CHAPTER 2

METHODS

Study Sites

The multimodal scarecrows (Figures 1 and 2) and cameras were set up in Struwig Eco Reserve in Olifants River East Conservancy (OREC), part of the Balule Nature Reserve in Limpopo Province, South Africa and Cheviot Farm in Tzaneen, Limpopo Province, South Africa.

The Struwig study site represents a semi-arid savanna/bushveld habitat. Cameras were set up at a junkyard (Figure 1). Most video captures at this site occurred during the day. Three camera traps were installed to record movement in the Struwig study site. Most of the nocturnal video captures occurred at Cheviot Farm, which has a subtropical habitat and much denser vegetation than the Struwig site (Figure 2). The Cheviot Farm site had two camera traps. Both sites experienced nocturnal and diurnal traffic from animals. For this project, only the nocturnal data were analyzed.



Figure 1 Struwig site in Struwig Eco Reserve in Olifants River East Conservancy (OREC), Balule Nature Reserve, Limpopo Province, South Africa (Richardson, 2014).

The blue arrow points to the speakers and orange strobe light of the multimodal scarecrow.



Figure 2 Cheviot Farm multimodal scarecrow (under foliage) and camera setup at Cheviot Farm, Tzaneen, Limpopo Province, South Africa (Richardson, 2014).

Experimental setup

The multimodal scarecrow mechanism described by Richardson (2014) was used for this experiment. The multimodal scarecrow was developed by Dr. Michael Stokes and Dr. Mark Cambron, from the Biology and Engineering departments at Western Kentucky University, respectively. Motion sensors activate the device, initially turning on orange strobe light followed by playback of a sound-file. The sound files were approximately 20 seconds in length and encompassed a range of animal and mechanical/human sounds that were presumed to be aversive to the nocturnal crop raiders (Table 1). Although the multimodal scarecrows were originally developed to release scent as well as produce visual and auditory stimuli (Richardson 2014), this mechanism was not used during the present study. The multimodal scarecrows were maintained and video files were collected by Samantha Gerber, a research technician for Balule Nature Reserve.

Table 1: Sound file name and numbers of video captures. In the case that a video's time stamp indicated that the video file was immediately preceded by a video file with a scarecrow activation; the later video file did not always show a scarecrow activation. Because these videos were so closely coupled with previous videos with successful activations, the sound file was listed as 'none but preceded by capture with sound file.'

Sound File	Number of Video Captures
baboon1	13
baboon2	6
baboon3	4
baboon4	2
baboon5	5
car1	5
car2	1
eagle1	1
eagle2	2
elephant	6
francolin	9
game viewer engine	13
helicopter	6
humans yelling	10
impala	2
leopard growl	12
malfunction1	1
malfunction2	1
none	19
none but preceded by capture with sound file	5
snake	8
trailer1	3
trailer2	1
unidentified animal	6
vervet	3
wildebeest	1

Sample size

Eleven different species were identified. A presumptive total of 155 adult individuals and 6 juvenile individuals were identified. Although all effort was made to prevent pseudoreplication, there was no way to ensure that each animal was not represented in another video capture. Therefore, all totals were regarded as presumptive, since there was no way to determine definitively that the same animal did not appear multiple times. All juvenile individuals were bushpigs or porcupines. Although sexual dimorphism is present in all recorded species, I was unable to assign gender in most cases. The largest sample sizes were bushpigs (74 individuals), porcupines (51 individuals), and genets (23 individuals). The species of genet were not distinguished. Both large-spotted and small-spotted genets were present, but not all genets could be differentiated. All other species had sample sizes of fewer than five individuals and are not considered further in analyses on a species level (Table 2).

Table 2 Sample size of species. Throughout the rest of this paper, animals are referred to by the common name.

Species	Common Name	Sample Size
<i>Canis adustus</i>	side striped jackal	3
<i>Canis mesomelas</i>	black backed jackal	1
<i>Civettictis civetta</i>	civet	2
<i>Genetta genetta/ Genetta tigrina</i>	genet	23
<i>Hystrix africaeaustralis</i>	Cape porcupine	51
<i>Mellivora capensis</i>	honey badger	1
<i>Otolemur crassicaudatus</i>	greater bushbaby	3
<i>Panthera pardus</i>	leopard	1
<i>Potamochoerus larvatus</i>	bushpig	74
<i>Sylvicapra grimmia</i>	duiker	1
<i>Tragelaphus scriptus</i>	bushbuck	1

Although the recording time of the camera was set to be 120 seconds, many video files were shorter than the expected time due to battery failure. Batteries purchased in South Africa were unable to deliver the sustained current necessary to illuminate a 2-minute night scene. In cases where multiple, short video files showed an individual in succession, the data reflected this through focal numbering. Some individuals were present through multiple scarecrow activations. Excluding videos omitted to prevent pseudoreplication, 40 individuals appeared in more than one video. Two focal animals appeared in six videos each, while three focal animals appeared in four videos each. Eleven focal animals appeared in three videos each, and 24 focal animals appeared in two videos each.

Video Selection, Sampling, and Recording Rules:

I used the Richardson (2014) ethogram as a template for the ethogram I constructed. Some definitions had to be added or modified in order to complement the species and data upon which I focused (Table 3). Although both diurnal and nocturnal videos were collected, for my study I limited analysis to nocturnal crop raiders. Because some video files share the same name, the date from the video was also noted. Dates were written as day/month/year and were obtained from the time-stamp on the first frame of each video file. Some sites had video capture from more than one angle. In this case, the more complete video capture was used for data collection in order to prevent pseudoreplication. Video captures of the same individuals at different times were used in data collection, but to prevent pseudoreplication, these instances were noted and the individuals were assigned the same focal number as their first entry. Eleven video files provided no new data as they were different views of other video captures.

Table 3 Ethogram of behavioral states and events used for video analysis. Only states and events that actually occurred in analyzed videos are included.

States	Events
Climb: Locomotion using hands and feet to travel in a vertical direction, often on a tree. (Cl)	Jump (J): A movement during which none of the animal's feet are in contact with a substrate.
Congregate: Members of the same species position themselves in close contact, even touching, with one another. The individuals remain in a small cluster, but may exhibit small movements within the cluster. (C)	Look (L): A discrete event during which the animal changes the orientation of its head either vertically or horizontally. If foraging, animal must distinctly shift its head as a response to something unrelated to its foraging behavior.
Feed (F): All activities related to handling and consuming food, excluding carrying food in mouth or hands while moving.	Other (O): Non-alarm call vocalization.
Forage (Fo): All activities related to searching for food.	Stand up (Su): Animal stands on hind legs OR reverts from a sitting position to an upright position.
Forage while walking (Fo/W): Animal searches for food conducting a leisurely-paced rolling gait. Snout is often touching the ground.	Startle (St): A pronounced flinch.
Not visible (NV): Animal is not in the field of view.	<i>States and Events adapted from Richardson (2014).</i>
Run (R): A quick-paced gait. Can include pauses < one second.	
Sit (Si): Includes all periods when an animal is seated (rear of animal is lowered and stationary).	
Stand (S): Includes all periods when an animal has all four feet on the ground.	
Walk (W): A leisurely-paced gait. Can include pauses < one second.	

When numbering focal animals in videos with more than one individual present, preference was given to the animal appearing in the video first. If more than one animal was present at the same time, the animal closest to the camera was given highest priority.

Nocturnal activity was obtained from 159 video files with 12,932 seconds (215.5 min) of footage. A presumptive total of 161 individual animals was observed.

To analyze the video footage, I focused on one focal animal at a time, viewing the footage at full screen at least once per focal. If the animal performed an event not specified in the ethogram, the event was listed as “other” and explained in the “notes on focal” column. The start and end time of the audio file was recorded in order to determine whether a reaction was due to a specific mechanism of the scarecrow (flashing lights, clicks, or the actual sound playing). Not all sounds played once the scarecrow was activated. Scarecrow start time refers to the time at which the actual sound-byte began rather than the click that signaled the activation of the sound file. The sound file the scarecrow played was recorded to examine the relationship between sound file and individual reaction. Some of the sound files degraded over time, making a positive identification difficult. In some cases, no sound played, but the scarecrow’s light mechanism was activated. For analytical purposes, the scarecrow mechanism refers to the complete activation (lights flashing and sound playing) of the scarecrow.

Data Recording

Data were recorded in a Microsoft Excel 2013 (Microsoft Corporation 2013) spreadsheet.

Data Analysis

Data analyses were dependent on the hypotheses tested and the sample sizes present. For all analyses, significance was set at $P > 0.05$. Data were analyzed using Statistica 13 (Dell October 2015).

Analysis of Feeding Behavior

To test the effect the scarecrow had on feeding time, I examined those video files that were at least 40 seconds in length and in which the scarecrow was not activated until at least 20 seconds into the video footage with at least 20 seconds of footage following scarecrow activation. If sample sizes were not suitably large, data were described qualitatively. The amount of time an individual spent feeding (or engaging in behaviors associated with feeding, such as foraging and foraging while walking) during the 20 seconds before the scarecrow was activated was compared to the amount of time the same individual spent in feeding behaviors in the 20 seconds following the initial activation of the scarecrow. Animals had to be visible for the full 40 seconds for the data to be included in the statistical analysis. To prevent pseudoreplication, in the event that a focal animal was recorded in more than one capture, a random sample was chosen using Microsoft Excel's RANDBETWEEN function. For bushpig and porcupine, the data were analyzed using Wilcoxon matched pairs tests. Significance level was set at $P=0.05$ for two-tailed tests.

Analysis of Running Behavior

To examine the effect of the scarecrow on running behavior, video captures during which animals ran were examined and compared to control videos in which no scarecrow was activated. To allow enough time for the behavioral states and any changes in behavior to be examined, videos less than 30 seconds in length were not analyzed, nor were videos in which the scarecrow was activated fewer than 15 seconds into the video capture.

No animals in the control videos ran, so all analyses of running behavior were based on video files with successful scarecrow activation. The videos that did display running behavior and met the time criteria were analyzed to see if the behavioral state occurred before the scarecrow activation or as a possible result of the activation. The only species of animal having a sufficient sample size for analysis of running behavior was bushpig.

Because no animals ran during videos without a sound file activation, the control for the analysis came from the video files with running behavioral states. Because the camera emits a small sound when activated, the first 15-30 seconds of the video capture was used as a control. Instances of animals running occurring during this control period were recorded and analyzed using Fisher's exact test to compare their likelihood of occurrence to instances of animals running occurring during the scarecrow mechanism, which was signaled by the initial click accompanying the activation. Significance level was set at $P=0.05$ and tests were one-tailed, as the hypothesis was that running was more likely following scarecrow activation.

Analysis of Looking Events

Looking events were considered indications of vigilance, as looking indicated that the animal was surveying its surroundings. To determine if vigilance was affected by the scarecrow activation, the frequency of looking events before and after the scarecrow activation was recorded. If the animal did not leave in the 20 seconds following the scarecrow's activation, the number of looking events in the 20 seconds before the activation were compared to the number of looking events in the 20 seconds after the activation. The sign test was used in order to determine if looking events were greater

following the scarecrow activation, indicative of vigilance. Because vigilance limits the time an animal spends feeding by forcing the animal to observe its surroundings, increased vigilance represents a secondary success of the scarecrow mechanism, and as such was included in the statistical analyses of the data. To prevent pseudoreplication, in the event that a focal animal was recorded in more than one capture, a random sample was chosen using Microsoft Excel's RANDBETWEEN function. Significance level was set at $P=0.05$ for two-tailed tests.

CHAPTER 3

RESULTS

Analysis of Feeding Behavior

In all three study species, animals display a significant decrease in duration of feeding and foraging behavior following the activation of the multimodal scarecrow.

Time spent by bushpig engaging in feeding and foraging behaviors differed significantly before the multimodal scarecrow was activated compared with the duration of these behaviors after activation ($P = 0.0006$). Of the 34 samples of bushpig that followed the sampling rules outlined for the feeding behavior analysis (Table 4), duplicates were randomly selected to be rejected, and the revised sample size was used for analysis ($N = 27$). Mean feeding time before the multimodal scarecrow was activated was 15.44 s, with a range of 0 s to 20 s, a median of 20 s, and a standard deviation of 7.856 s. Mean feeding time after the activation was 7.11 s, with a range of 0 s to 20 s, a median of 0 s, and a standard deviation of 8.898 s. Bushpig spent significantly less time eating after the multimodal scarecrow was activated compared with the feeding activity prior to activation.

Table 4 Data for time spent feeding by bushpig in 20-second intervals before and after the multimodal scarecrow was activated. Although all eligible samples are presented in the table below, to prevent pseudoreplication, if a focal animal was recorded in more than one capture, a single video capture was randomly chosen using Microsoft Excel's RANDBETWEEN function.

Video File	Focal Animal Number	Time spent feeding (20s before)	Time spend feeding (20s after)	Total time spent feeding out of 40s
VIDO0011(2)	33	20	0	20
VIDO0023(2)	40	18	20	38
VIDO0024	43	20	20	40
VIDO0027	43	19	9	28
VIDO0024	44	20	20	40
VIDO0032	46	19	0	19
VIDO0032	47	0	0	0
VIDO0039	53	20	6	26
VIDO0039	54	19	0	19
VIDO0046(2)	56	20	20	40
VIDO0050	59	20	15	35
VIDO0050	60	9	6	15
VIDO0061	81	0	0	0
VIDO0061	82	0	0	0
VIDO0063	85	20	20	40
VIDO0120	88	20	20	40
VIDO0162	92	20	6	26
VIDO0054	95	20	14	34
VIDO0056	95	19	0	19
VIDO0061	95	20	20	40
VIDO0054	96	19	17	36
VIDO0056	96	20	19	39
VIDO0059	96	20	16	36
VIDO0061	96	19	20	39
VIDO0132	100	20	20	40
pigs sound	123	14	0	14
VIDO0126 (2)	137	0	0	0
VIDO0008	144	20	1	21
VIDO0009	145	20	1	21
VIDO0009	146	20	0	20
VIDO0011(2)	147	20	0	20
VIDO0011	148	20	0	20
VIDO0013	148	19	0	19
VIDO0250	156	0	0	0

Cape porcupine showed significant differences in feeding time before and after the multimodal scarecrow activation ($P = 0.046$). Of 16 eligible samples for Cape porcupine feeding behavior analysis (Table 5), duplicates of focal animals were randomly rejected ($N = 12$). Mean feeding time before the activation was 14.25 s, with a range of 0 s to 20 s, a median of 18.00 s, and a standard deviation of 7.605 s. Mean feeding time after multimodal scarecrow activation was 10.00 s, with a range of 0 s to 20 s, a median of 11.00 s, and a standard deviation of 8.560 s. On average, Cape porcupines spent significantly less time feeding after the multimodal scarecrow was activated. Some individuals left with food held in their mouths, indicating that, although they were still crop raiding, they were not remaining in the area for long periods.

Table 5 Data for time spent feeding by Cape porcupine in 20-second intervals before and after the multimodal scarecrow was activated. Although all eligible samples are presented in the table below, to prevent pseudoreplication, if a focal animal was recorded in more than one capture, a single video capture was randomly chosen using Microsoft Excel's RANDBETWEEN function.

Video File	Focal Animal Number	Time spent feeding (20s before)	Time spent feeding (20s after)	Total time spent feeding out of 40s
VIDO0007	32	20	11	31
VIDO0014	36	20	20	40
VIDO0057	64	16	0	16
VIDO0022	75	20	20	40
VIDO0022	76	20	20	40
VIDO0025(2)	77	20	20	40
VIDO0025(2)	78	10	2	12
VIDO0061	83	0	0	0
VIDO0084	97	0	0	0
VIDO0089	97	20	18	38
VIDO0090	97	0	0	0
VIDO0089	98	20	11	31
VIDO0121	99	20	11	31
VIDO0122	99	14	4	18
VIDO0148	102	20	20	40
VIDO0150	102	11	12	23

Seven samples were collected for analysis of the effect the multimodal scarecrow had on genet feeding behavior (Table 6). Genet displayed significant difference in the duration of feeding behavior before and after the activation of the multimodal scarecrow ($P = 0.028$). Mean feeding time for genet before activation was 15.14 s, with a range of 0 s to 20 s, a median of 19 s, and a standard deviation of 7.581 s. Genet mean feeding time following activation was 8.00 s, with a range of 0 s to 17 s, a median of 5 s, and a standard deviation of 7.461 s. On average, genets spent significantly less time feeding following the activation of the multimodal scarecrow.

Table 6 Data for time spent feeding by genet in 20-second intervals before and after the multimodal scarecrow was activated. Each sample was presumed to be a unique genet individual, so no data was discarded for analysis.

Video File	Focal Animal Number	Time spent feeding (20s before)	Time spent feeding (20s after)	Total time spent feeding out of 40s
VIDO0007	16	20	17	37
VIDO0021	39	20	5	25
VIDO0045	57	20	16	36
VIDO0088	86	10	4	14
VIDO0017	109	19	14	33
VIDO0063	112	17	0	17
VIDO0003 (2)	127	0	0	0

One greater bushbaby (Focal animal number 108) spent 20 seconds feeding in the test interval before the multimodal scarecrow was activated and 17 seconds feeding following the activation. Observationally, the bushbaby spent less time feeding after the multimodal scarecrow was activated than before.

Analysis of Bushpig Running Behavior

Bushpig running behavior was significantly dependent upon the presence of the multimodal scarecrow ($P = 0.0003$, one tail). Of the 15 bushpigs sampled for the analysis of running behavior, three ran before the multimodal scarecrow was activated, compared with 12 that did not run during the control period. During the experimental time interval of the 20s following the activation of the multimodal scarecrow, 13 bushpigs ran and two bushpigs did not run (Table 7).

Table 7 Data for statistical analysis of number of bushpigs that ran. Expected value for the Fisher's exact test was taken from the control data. From Fisher's exact test P (one tail) = 0.0003.

	Run	No Run	Total
Control (before scarecrow activation)	3	12	15
Experimental (after scarecrow activation)	13	2	15

Besides bushpig, six other species had representatives with instances of running behavior, but no statistical analyses could be made due to the small sample sizes. All black backed and side striped jackals recorded were seen running for 1-2 s exclusively at the start of the video capture. Only one side striped jackal returned to the camera's field of view. The duiker individual was observed running during the first two seconds of the video capture and did not return to the field of view. The honey badger individual ran for one second following the activation of the multimodal scarecrow.

Both porcupine and genet species had representatives with instances of running behaviors, but the video captures did not follow the sampling rules for tests of

significance. For porcupines, in three of the four instances of running behaviors, the multimodal scarecrow was definitively activated and the animal ran during the playback of the sound file, indicating success of the multimodal scarecrow. In the fourth instance, the video file (VIDO0061) was one second long, making it impossible to determine if the multimodal scarecrow was activated. In genets, six instances of the running behavioral state were recorded. All running behavioral states took place during captures with successful multimodal scarecrow activation, although in two instances the animals stopped running before the multimodal scarecrow was activated.

Analysis of Looking Events

In all three study species, looking event frequency was not significantly affected by the activation of the multimodal scarecrow.

The number of recorded look events performed by bushpig did not significantly differ in the time intervals before and after the activation of the multimodal scarecrow ($P = 0.20$). Of 52 samples that were eligible for analysis based on previously outlined rules, seven samples were randomly rejected to avoid including duplicate focal animals in the analysis (Table 8). The range for bushpig looking events before the multimodal scarecrow was activated was 0 events to 8 events, with a median of 1 event. The mean number of looking events prior to activation for bushpig was 1.38 events. The mean number of looking events following the multimodal scarecrow activation was 1.36 events. The number of bushpig looking events following activation ranged from 0 events to 7 events, with a median of 0 events. The scarecrow does not have a significant effect on the frequency of looking events in bushpig.

Table 8 Number of looking events for bushpig 20 seconds before the multimodal scarecrow activation and 20 seconds after the activation. Although all eligible samples are presented in the table below, to prevent pseudoreplication, if a focal animal was recorded in more than one capture, a single video capture was randomly chosen using Microsoft Excel's RANDBETWEEN function.

Video File	Focal Animal Number	Looking events before scarecrow	Looking events after scarecrow	Video File	Focal Animal Number	Looking events before scarecrow	Looking events after scarecrow
VIDO0011(2)	33	0	0	VIDO016 2	92	0	3
VIDO0023(2)	40	4	7	VIDO005 1	94	2	0
VIDO0023(2)	41	0	0	VIDO005 4	95	0	3
VIDO0024	43	0	0	VIDO005 6	95	0	4
VIDO0027	43	1	4	VIDO005 9	95	0	3
VIDO0024	44	0	0	VIDO006 1	95	1	1
VIDO0032	46	0	0	VIDO005 4	96	1	4
VIDO0032	47	6	0	VIDO005 6	96	0	1
VIDO0032	48	0	0	VIDO005 9	96	0	2
VIDO0032	49	1	1	VIDO006 1	96	1	2
VIDO0032	50	0	4	VIDO013 2	100	2	1
VIDO0039	53	2	0	VIDO013 2	101	0	0
VIDO0039	54	0	2	VIDO015 2	103	1	0
VIDO0046(2)	56	1	1	VIDO015 2	104	0	5
VIDO0050	59	2	0	pigs sound	123	6	1
VIDO0050	60	2	4	pigs sound	124	2	1
VIDO0074	69	1	1	run	125	5	2
VIDO0074	70	0	0	run	126	4	1
VIDO0061	80	0	0	VIDO011 0	135	0	0
VIDO0061	81	1	6	VIDO012 5	136	1	0
VIDO0061	82	0	0	VIDO012 6 (2)	137	8	3
VIDO0063	85	0	1	VIDO000 8	144	0	0
VIDO0120	88	0	1	VIDO000 9	146	3	0
VIDO0120	89	0	0	VIDO001 1(2)	147	2	0
VIDO0131	90	0	0	VIDO025 0	156	3	7
VIDO0131	91	0	0	VIDO025 0	157	2	2

There was no significant difference in frequency of looking events in Cape porcupines before the multimodal scarecrow activation compared with after the activation ($P = 0.12$). Of 11 eligible samples based on the sampling rules, one duplicate focal individual was randomly rejected from analysis, leaving a sample size $N = 10$ (Table 9). The range for number of looking events recorded in Cape porcupine prior to the activation of the multimodal scarecrow was 0 events to 3 events, with a median of 0 events. The mean number of looking events prior to activation was 0.60 events. The range for number of looking events following the multimodal scarecrow activation was 0 events to 3 events, with a median of 1 event. The mean number of looking events in Cape porcupine following the activation of the multimodal scarecrow was 1.00 events.

Table 9 Number of looking events for Cape porcupine 20 seconds before the multimodal scarecrow activation and 20 seconds after the activation. These data do not include those animals that left in the 20 seconds following the activation. Although all eligible samples are presented in the table below, to prevent pseudoreplication, in the event that a focal animal was recorded in more than one capture, a single video capture was randomly chosen using Microsoft Excel's RANDBETWEEN function.

Video File	Focal Animal Number	Number of looking events 20s before scarecrow	Number of looking events 20s after scarecrow
VIDO0007	32	1	3
VIDO0014	36	0	0
VIDO0023	42	0	0
VIDO0022	75	0	1
VIDO0022	76	0	0
VIDO0024	77	0	1
VIDO0025(2)	77	0	0
VIDO0025(2)	78	3	1
VIDO0089	97	0	0
VIDO0089	98	1	2
VIDO0148	102	1	2

There was no significant difference in the frequency of looking events recorded in genet before the multimodal scarecrow activation compared with after the activation ($P = 0.41$). Because no individual focal genet animals were represented more than once in eligible samples for analysis, sample size directly reflects the number of eligible samples ($N = 7$) (Table 10). The range for the number of looking events recorded in genets prior to the multimodal scarecrow activation was 0 events to 7 events, with a median of 2 events. The mean number of looking events recorded prior to activation was 2.00 events. Following the activation of the multimodal scarecrow, the range for the number of looking events recorded in genets was 0 events to 7 events, with a median of 3 events. The mean number of genet looking events following activation was 3.00 events. As mesopredators, genets perform looking events frequently, which may account for the relatively high frequency of looking events before and after the multimodal scarecrow was activated, but statistical analyses suggest that looking event frequency in genets is not significantly affected by the presence and activation of the multimodal scarecrow.

Table 10 Number of looking events for genet 20 seconds before the scarecrow activation and 20 seconds after the activation. These data do not include those animals which left in the 20 seconds following the scarecrow activation.

Video File	Focal Animal Number	Number of looking events 20s before scarecrow	Number of looking events 20s after scarecrow
VIDO0007	16	0	3
VIDO0014	37	0	0
VIDO0021	39	2	5
VIDO0045	57	0	2
VIDO0088	86	3	7
VIDO0017	109	7	4
VIDO0063	112	2	0

CHAPTER 4

DISCUSSION

The multimodal scarecrow was demonstrably successful in discouraging destructive behaviors of bushpig, Cape porcupine, and genet. Bushpig and Cape porcupine are reported by farmers to be major nocturnal crop raiders (Naughton-Treves and Treves, 2005). The multimodal scarecrow reduced duration of destructive feeding and foraging behaviors in all species with sufficient data for analysis. When the animals did not leave the site during the 40-second interval of analysis, the decrease in foraging and feeding behaviors following the activation of the multimodal scarecrow prevented the animal from maximizing foraging success. Statistically, the animal is spending less time feeding and foraging following the multimodal scarecrow activation than it is prior to the activation. The 20 seconds prior to the activation of the multimodal scarecrow acted as a control, as it represented the state of nocturnal crop raiders in the absence of the multimodal scarecrow as a frightening device. Because animals want to maximize foraging efficiency to offset against energy loss and travel time associated with their feeding behaviors (Pyke, 1981), sites equipped with the multimodal scarecrow may begin to experience less nocturnal crop-raider traffic because the multimodal scarecrow prevents the animal from foraging optimally.

A study that tags a representative sample of each population to be tracked would be useful in determining whether animals preferentially avoid areas equipped with

multimodal scarecrows. Such a study could be accomplished by setting up control sites with motion-activated cameras, but without the multimodal scarecrows, and comparing traffic by recording how many times tagged animals attend each site and recording the duration of the animal's activity in each site. The control sites should be near enough to the experimental sites that the animal does not spend more energy getting to the control site than it would gain from foraging there, and far enough away from the experimental sites that the multimodal scarecrow would not affect the animals at the control sites.

Although running behavior could only be analyzed for bushpig, the success of the multimodal scarecrow in terms of bushpigs fleeing as a response to the stimuli represents a very effective method of crop-raiding deterrence, as bushpigs are consistently listed among the top crop-raiding pest species in agricultural areas of Africa (Naughton-Treves and Treves, 2005). Across all analyses in this study, bushpig was the species that was most represented in terms of sample size. A decrease in the heavy presence of bushpig crop-raiders would likely have a significant positive impact in terms of reducing crop loss caused by foraging by nocturnal pest animals in the area of study.

Further data collection and analyses documenting larger samples would be useful in determining if running behavior in Cape porcupine and genets can be attributed to the multimodal scarecrow. Although there were not sufficient samples to analyze, qualitatively, there seemed to be a positive correlation between the activation of the multimodal scarecrow and Cape porcupine and genets running. Additionally, examining whether or not an animal returned following an exit attributed to the multimodal

scarecrow would be beneficial in demonstrating the short-term efficacy of the multimodal scarecrow.

Although the analyses did not provide evidence for an increase in the incidence of looking events, further analyses and data collection are necessary to examine the effect the multimodal scarecrow has on vigilance. Burger and Gochfeld (1994) describe vigilance as scanning behavior and other observational behaviors. Nocturnal videos could be analyzed for the presence and duration of scanning behavior following the same sampling rules as outlined in this study. Such an analysis may provide a more accurate depiction of the effects the multimodal scarecrow has on vigilance in nocturnal crop raiders.

The multimodal sensory pathways that provide auditory and visual stimuli seem observationally to be more effective than partial activations of the multimodal scarecrow. Although no analyses were conducted to examine the difference in behaviors when only part of the scarecrow was activated, in the instances that the multimodal scarecrow was not completely activated (i.e., the sound did not play), the responses of animals were not as strong as responses during complete activation. Further research examining the behavioral responses animals have to the auditory and visual signals separately compared to behavioral responses to the multimodal scarecrow could serve to demonstrate additive effects of multi-sensory stimuli.

Bomford and O'Brien (1990) suggest that different categories of sounds have different levels of efficacy at deterring animals. In the present experiment, a variety of sound files were used. Although no analyses were performed to determine if certain sound files or sound file categories had greater instances of success, the data are suitable

for conducting such analyses. Using the parameters that were statistically significant in determining the efficacy of the multimodal scarecrow, the sound files may be analyzed for relative efficiency. In the case of feeding and foraging behaviors, which for this study are considered damaging behaviors, the data analyzed may be further divided to determine if a particular type of sound affected the duration of feeding and foraging behaviors. Bushpig running behavior could also be analyzed to see if running was associated with certain sound file types over others. Because looking events were not affected by the multimodal scarecrow, analysis of sound files in relation to frequency of looking events would not be a beneficial avenue to explore.

Additionally, further data collection and analyses could provide insight into the long-term efficacy of the multimodal scarecrow, especially over multiple seasons. While Beringer et al. (2003) suggest that scarecrows are only effective in the short term due to the risk of habituation, a study by Götz and Janik (2011) demonstrated that repeated startle responses to an acoustic trigger led to sensitization and avoidance behavior in grey seals. The Götz and Janik (2011) study suggests that a stimulus which triggers a certain level of fear response may be effective long term. If the multimodal scarecrow, as a frightening device, can be optimized to elicit the greatest fear responses in nocturnal crop raiders, the nocturnal pest animals may avoid sites guarded by the multimodal scarecrows, thereby mitigating the destructive behaviors. However, even if the multimodal scarecrow does not prevent crop raiders from traveling to the sites, reduced duration of damaging feeding and foraging, as seen in this study, may also be effective in reducing the negative impact of nocturnal crop raiders.

The results of this study suggest that a motion-activated, multimodal scarecrow is successful in deterring damaging foraging and feeding behavior in nocturnal crop raiders. Further data collection and analyses may be used to optimize the efficacy of the multimodal scarecrow, but the behavioral responses of animals in this study suggest that the multimodal scarecrow may be a useful tool in reducing human-wildlife conflict between farmers and nocturnal crop-raiders in South Africa

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APPENDIX A

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